STATE OF FLORIDA
DEPARTMENT OF NATURAL RESOURCES
Randolph Hodges, *Executive Director*

DIVISION OF INTERIOR RESOURCES
Robert O. Vernon, *Director*

BUREAU OF GEOLOGY
C. W. Hendry, Jr., *Chief*

REPORT OF INVESTIGATIONS NO. 68

HYDROGEOLOGIC ASPECTS OF A PROPOSED SANITARY LANDFILL NEAR OLD TAMPA BAY, FLORIDA

By
R. N. Cherry and D. P. Brown

Prepared by the
U. S. GEOLOGICAL SURVEY
in cooperation with
BUREAU OF GEOLOGY
FLORIDA DEPARTMENT OF NATURAL RESOURCES
and the
CITY OF CLEARWATER

Tallahassee, Florida
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LETTER OF TRANSMITTAL

Bureau of Geology
Tallahassee
December 17, 1973

Honorable Reubin O'D. Askew, *Chairman*
Department of Natural Resources
Tallahassee, Florida 32304

Dear Governor Askew:

The Department of Natural Resources, Bureau of Geology, is publishing as its Report of Investigation No. 68 the report entitled, "Hydrogeologic Aspects of a Proposed Sanitary Landfill near Old Tampa Bay, Florida," by R. N. Cherry and D. P. Brown of the U. S. Geological Survey.

The use of a sanitary landfill for solid-waste disposal overcomes some of the serious health and esthetic problems that are associated with open-dump disposal. However, unless the landfill site is selected and properly operated with respect to the hydrologic environment, leachate from the landfill site may contaminate the water resources of the area.

This study of a particular sanitary landfill site is published in order to provide guidelines which may be incorporated in evaluating other potential sanitary landfill sites.

Respectfully yours,

C. W. Hendry, Jr., *Chief*
Bureau of Geology

Completed manuscript received
November 9, 1973
Printed for the
Florida Department of Natural Resources
Division of Interior Resources
Bureau of Geology
by
Ambrose the Printer, Inc.
Jacksonville, Florida

Tallahassee
1974

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HYDROGEOLOGIC ASPECTS OF A PROPOSED SANITARY LANDFILL NEAR OLD TAMPA BAY, FLORIDA

By
R. N. Cherry and D. P. Brown

ABSTRACT

The proposed sanitary landfill site for the city of Clearwater is in east-central Pinellas County near Old Tampa Bay. The area of the site is about 320 acres.

The site is about 50 feet above mean sea level and is partly drained by two unnamed streams. One stream is a tributary of the Lake Tarpon outfall canal; the other stream, a tributary of Bishop Creek, drains into the north end of Old Tampa Bay.

The two aquifers in the area are a shallow aquifer, which is composed of sand containing a limestone zone, and the Floridan aquifer, which is composed of limestone. At the site of the proposed landfill, the two aquifers are separed, on the average, by 35 feet of clay, that forms a confining layer of low vertical permeability. The head difference between the shallow and Floridan aquifers is 40 feet, and the rate of vertical movement within the proposed landfill site from the shallow aquifer through the clay layer to the underlying Floridan aquifer is estimated to be 32,000 gallons per day in an area of 320 acres.

In the area of the proposed site, water moves laterally through both aquifers from west to east toward Old Tampa Bay. Water levels in the shallow aquifer within the proposed landfill site are less than 5 feet below land surface and range from about 30 to 60 feet above sea level. The potentiometric surface of the Floridan aquifer within the proposed landfill site ranges in elevation from about 6 to 10 feet above sea level.

The horizontal flow through the shallow aquifer from the proposed landfill site is estimated to be 314,000 gallons per day. The two streams at the site intercept about 190,000 gallons of ground water per day. The remainder, 124,000 gallons per day, moves as horizontal flow through the shallow aquifer toward Old Tampa Bay. At the estimated theoretical rate of horizontal movement of 2.7 feet per day through the shallow aquifer, water from the landfill site would reach Old Tampa Bay in about 2 years.

The site could be made hydrologically favorable for a sanitary landfill if some precautions are taken. A perimeter canal could intercept water leaving the site. Also, maintaining a monitoring system would allow early detection of possible movement of contaminated water.

INTRODUCTION

The disposal of about 200 tons of solid waste each day constitutes a major problem for the city of Clearwater. The disposal can lead to health, esthetic, and environmental problems. The public recognizes that many problems are associated with solid-waste disposal and their demands are increasing for properly selected, engineered, and effectively and economically operated solid-waste-disposal facilities.

The use of a sanitary landfill for solid-waste disposal overcomes some of the serious health and esthetic problems that are associated with open-dump disposal. However, unless the landfill site is selected and properly operated with respect to the hydrologic environment, leachate from the land fill site may contaminate the water resources of the area.

The sanitary landfill is defined by the American Society of Civil Engineers (1959) as "A method of disposing of refuse on land without creating nuisances or hazards to public health or safety, by utilizing the principles of engineering to confine the refuse to the smallest practical area, to reduce it to the smallest practical volume, and to cover it with a layer of dirt at the completion of each day's operation or at such more frequent intervals as may be necessary."

The sanitary landfill method of disposal is primarily a containment and compaction of material. It is a convenient disposal method by which all solid waste, irrespective of size, moisture, or other characteristics, can be disposed, and it consists of four basic operations:

1. The solid wastes are deposited in a controlled manner in a prepared part of the site,
2. The solid wastes are spread and compacted in thin layers,
3. The solid wastes are covered daily or more frequently, if necessary, with a layer of dirt,
4. The cover material is compacted daily.

PURPOSE AND SCOPE

The city of Clearwater is faced with a critical need to expand its sanitary landfill facilities. The city officials, aware of environmental problems commonly associated with sanitary landfills, entered into a cooperative agreement with the

U. S. Geological Survey to investigate a prospective landfill site. The purpose of this investigation was to evaluate the hydrologic consequences of operating a sanitary landfill northeast of the city of Clearwater. This report presents an evaluation of the site based on hydrologic conditions.

ACKNOWLEDGMENTS

Cooperation of Merrett Stierheim, City Manager; Max Battle, City Engineer; and N. J. Seher, Engineering Department, Clearwater, Florida, is gratefully acknowledged. The helpful cooperation of the property owners who permitted access to their land and wells in order to collect hydrologic data is greatly appreciated.

GEOGRAPHY

The proposed sanitary landfill site is about 7 miles northeast of Clearwater, just north of the intersection of State Roads 593 and 580 (fig. 1). The site covers about 320 acres, or one-half square mile.

Land surface in the area of the proposed site ranges in elevation from sea level at Old Tampa Bay to more than 80 feet above sea level at the crest of a ridge west of the landfill site (fig. 2 and table 1). In the proposed landfill site elevations of the land surface range from about 40 feet above sea level near the eastern boundary to about 65 feet above sea level near the west boundary. The western part slopes about 3 feet per 1,000 ft, and the eastern part about 10 feet per 1,000 ft.

The proposed site is drained by two unnamed streams; one drains northeastward into the Lake Tarpon outfall canal, and the other is a tributary of Bishop Creek (fig. 1).

HYDROGEOLOGY

The proposed sanitary landfill site is underlain by three hydrogeologic units. The uppermost unit consists of sand, sandy clay, and sandy limestone called the shallow aquifer, the middle unit is a clay confining layer, and the lower unit is the Floridan aquifer. Figure 3 shows the thickness of the uppermost and middle units in the proposed sanitary landfill site.

SHALLOW AQUIFER

The upper part of the shallow aquifer is an unconsolidated, fine to very fine, well sorted, yellowish-brown to dark-brown sand. The lower part of this

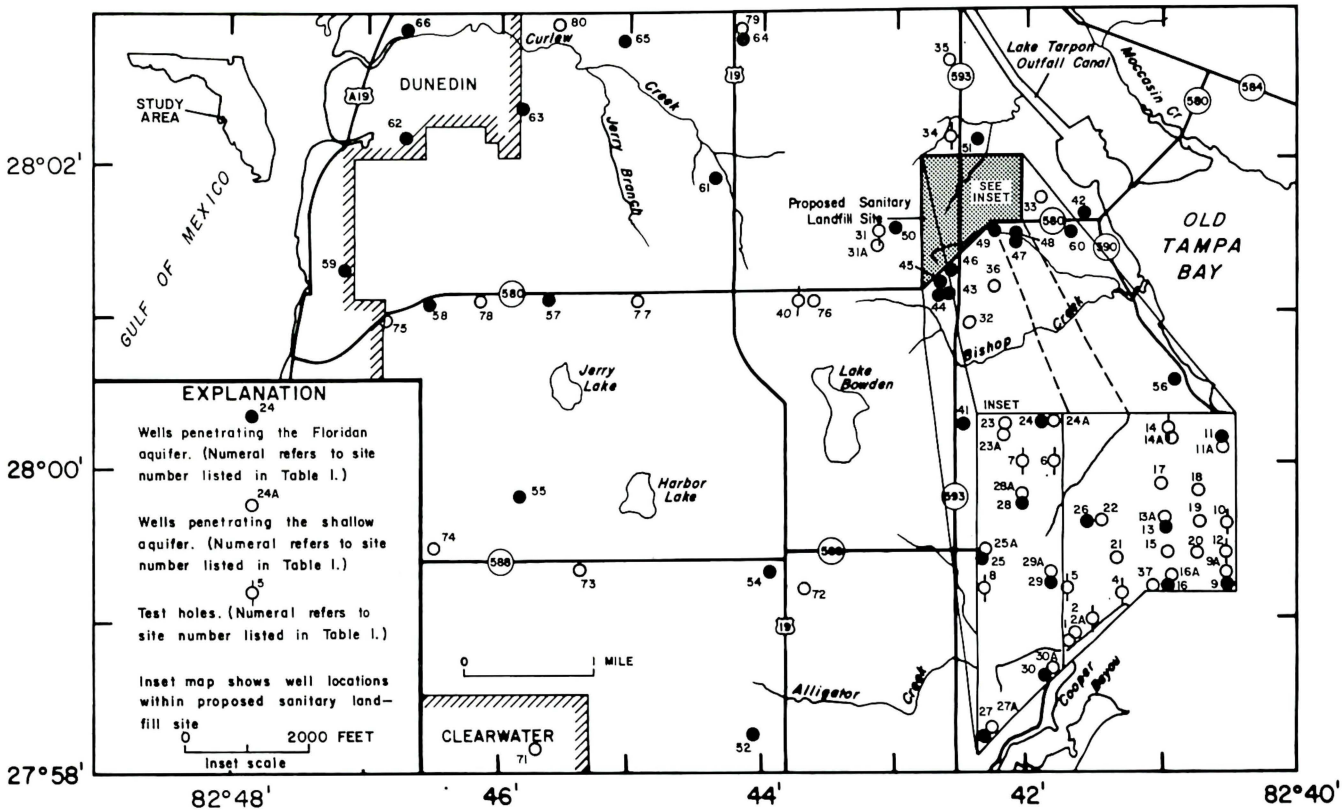


Figure 1. Proposed landfill and data-collection sites.

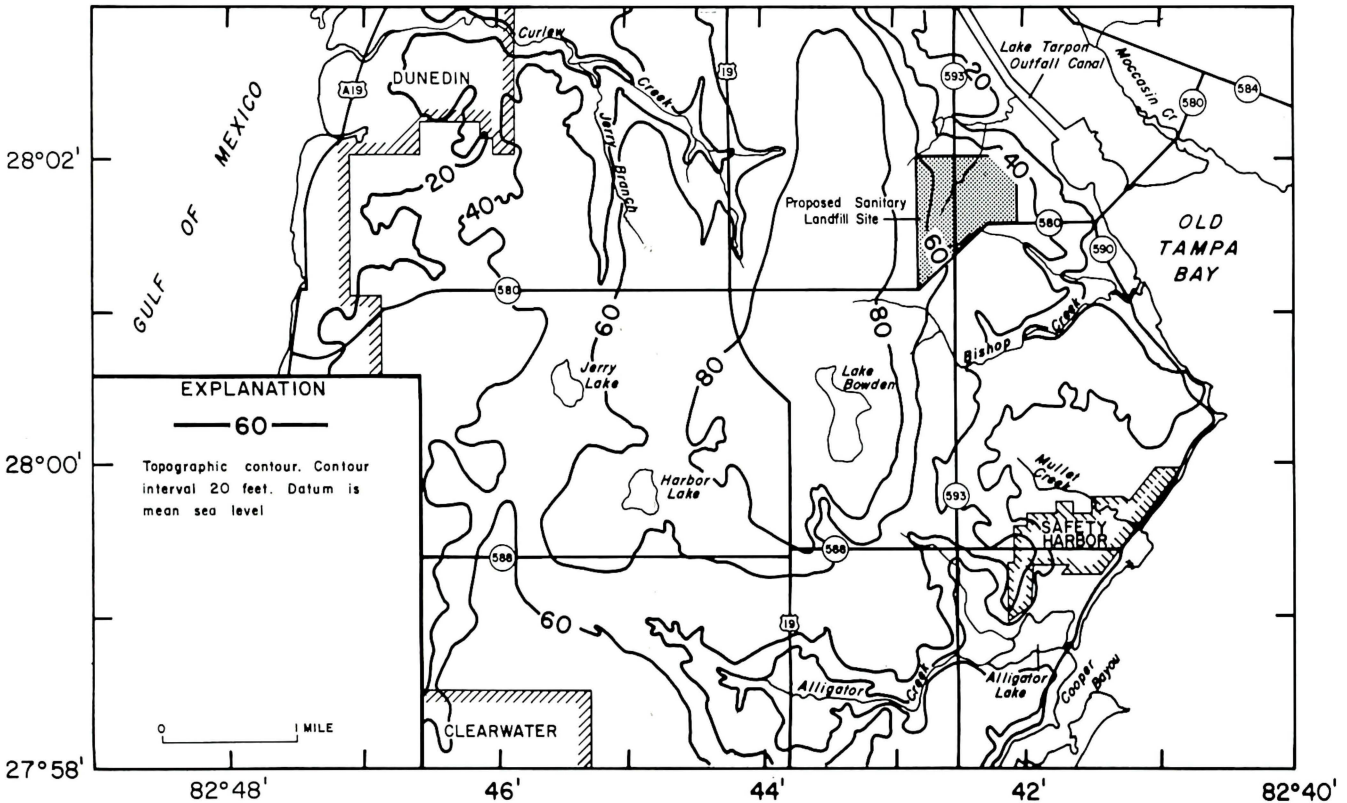


Figure 2. Topographic map of the proposed sanitary landfill site and adjacent area.

Table 1. General information concerning test, observation and domestic wells in the proposed sanitary landfill area (msl: feet above mean sea level)

SHALLOW AQUIFER

Site number	Well number	Well Depth (feet)	Casing Depth (feet)	Elevation land surface (msl)	Clay thickness (feet)	Depth to Floridan aquifer (feet)	Water level elevations			
							Date	msl	Date	msl
1	280127N0824232.1	17	15	57.80	13	-	4- 9-71	55.19	5-26-71	54.21
2	280127N0824232.2	15	13	57.80	13	-	4- 9-71	55.44	5-26-71	54.20
9A	280137N0824203.2	15	13	50.90	-	-	4- 9-71	45.80	5-26-71	45.35
11A	280159N0824204.2	15	13	35.94	-	-	4- 9-71	32.35	5-26-71	31.49
13A	280147N0824215.2	13	11	56.48	-	-	4- 9-71	54.06	5-26-71	52.62
14A	280200N0824212.2	15	12	45.30	-	-	4- 9-71	42.82	5-26-71	41.95
15	280142N0824214.1	13	10	57.18	-	-	4- 9-71	54.07	5-26-71	53.14
16A	280137N0824214.2	15	13	55.55	-	-	4- 9-71	53.15	5-26-71	52.25
17	280153N0824214.1	13	11	54.66	-	-	4- 9-71	51.66	5-26-71	50.97
18	280153N0824208.1	14	12	49.67	-	-	4- 9-71	43.44	5-26-71	47.83
19	280147N0824208.1	14	12	54.10	-	-	4- 9-71	49.06	5-26-71	48.51
20	280142N0824208.1	15	13	54.17	-	-	4- 9-71	50.35	5-26-71	49.52
21	280140N0824224.1	12	10	56.86	-	-	4- 9-71	54.32	5-26-71	53.51
22	280147N0824227.2	19	17	56.86	-	-	4- 9-71	53.74	5-26-71	52.85
23A	280202N0824242.2	12	10	53.86	-	-	4- 9-71	50.56	5-26-71	49.45
24A	280202N0824234.2	14	12	54.58	-	-	4- 9-71	51.71	5-26-71	50.63
25A	280143N0824248.2	15	13	63.48	-	-	4- 9-71	60.98	5-26-71	59.95
27A	280112N0824247.2	15	13	63.59	-	-	4- 9-71	61.51	5-26-71	60.12
28A	280147N0824238.2	15	13	58.48	-	-	4- 9-71	55.51	5-26-71	54.50
29A	280137N0824234.2	13	11	57.36	-	-	4- 9-71	55.11	5-26-71	53.87
30A	280123N0824234.2	20	18	59.50	-	-	4- 9-71	56.35	5-26-71	55.50
31A	280137N0824258.2	20	17	79.68	-	-	4- 9-71	77.78	5-26-71	77.24
32	280105N0824232.1	15	13	49.53	-	-	4- 9-71	46.37	5-26-71	46.30
33	280146N0824154.1	15	13	37.46	-	-	4- 9-71	35.03	5-26-71	34.62
35	280227N0824235.1	10	8	37.10	-	-	4- 9-71	34.59	5-26-71	33.54
36	280117N0824217.1	13	11	56.56	-	-	4- 9-71	54.06	5-26-71	54.30
37	280135N0824221.1	18	16	57.35	-	-	4- 9-71	53.36	5-26-71	52.50

SHALLOW AQUIFER – continued

Site number	Well number	Well Depth (feet)	Casing Depth (feet)	Elevation land surface (msl)	Clay thickness (feet)	Depth to Floridan aquifer (feet)	Water level elevations			
							Date	msl	Date	msl
71	275807N0824548.1	19.1	14.1	71.10	-	95	4-21-71	66.97	5-25-71	67.40
72	275914N0824341.1	16.0	11	57	-	49	4-20-71	52.59	5-25-71	52.80
73	275922N0824520.1	19.0	14	62.2	-	61	4-20-71	55.40	5-25-71	55.85
74	275933N0824623.1	39.0	34	30.5	-	40	4-20-71	9.24	5-25-71	9.50
75	280059N0824649.1	34.0	29	35.56	-	70	4-20-71	14.42	5-25-71	15.46
76	280108N0824338.1	50	48	97.1	-	85	4-20-71	92.61	5-25-71	92.85
77	280107N0824449.1	18.8	14	71.4	-	60	4-20-71	67.73	5-25-71	67.94
78	280107N0824604.1	14	10	30.5	-	40	4-20-71	26.73	5-25-71	27.13
79	280254N0824416.3	25	20	66.82	-	45	4-20-71	62.95	5-25-71	62.92
80	280251N0824530.1	19	14	25.2	-	30	4-20-71	-	5-21-70	17.00
				FLORIDAN AQUIFER						
9	280137N0824203.1	60	58	50.90	33	53	4- 9-71	7.85	5-26-71	8.30
11	280159N0824204.1	58	56	35.94	27	52	4- 9-71	7.14	5-26-71	6.89
13	280147N0824215.1	55	53	56.26	33	53	4- 9-71	-	5-26-71	-
16	280137N0824214.1	55	50	55.55	35	53	4- 9-71	-	5-26-71	7.21
23	280202N0824242.1	52	48	53.86	31	50	4- 9-71	11.10	5-26-71	10.88
24	280202N0824234.1	47	45	54.58	25	45	4- 9-71	-	5-26-71	-
25	280143N0824848.1	54	51	63.74	27	54	4- 9-71	-	5-26-71	-
26	280147N0824227.1	62	60	57.36	40	60	4- 9-71	9.25	5-26-71	9.28
27	280112N0824247.1	70	68	63.59	43	68	4- 9-71	9.48	5-26-71	9.53
28	280147N0824238.1	59	56	58.48	36	55	4- 9-71	8.42	5-26-71	8.29
29	280137N0824234.1	70	67	57.36	43	64	4- 9-71	-	5-26-71	-
30	280123N0824234.1	64	61	59.50	40	60	4- 9-71	9.16	5-26-71	9.28
41	280018N0824229.1	129	69	45	49	79	6- -46	42	5-26-71	-
42	280137N0824132.1	27	25	20	15	25	8- 1-65	9.00	5-26-71	-
43	280111N0824236.1	100	-	54	-	-	-	-	-	-
44	280111N0824237.1	-	-	59	-	-	-	-	-	-
45	280112N0824242.1	100	50	63	-	-	-	-	-	-
46	280119N0824235.1	200	-	59	-	-	-	-	-	-
47	280131N0824204.1	120	-	50	-	-	-	-	-	-
48	280133N0824204.1	111	-	50	-	-	-	-	-	-

FLORIDAN AQUIFER – continued

Site number	Well number	Well Depth (feet)	Casing Depth (feet)	Elevation land surface (msl)	Clay thickness (feet)	Depth to Floridan aquifer (feet)	Water level elevations			
							Date	msl	Date	msl
49	280134N0824215.1	110	70	56	-	-	-	-	-	-
50	280137N0824256.1	140	70	75	-	-	-	-	-	-
51	280204N0824223.1	-	-	50	-	-	-	-	-	-
52	275815N0824404.1	299	81	33.64	-	-	4-21-71	9.53	5-24-71	8.43
53	275845N0824135.1	58	58	4.7	-	-	4-21-71	.67	5-24-71	1.20
54	275917N0824352.1	-	-	67.18	-	-	4-20-71	11.05	5-24-71	11.35
55	275945N0824545.1	-	-	51	-	-	4-20-71	4.50	5-24-71	4.70
56	280035N0824054.1	90	25	30	-	-	4-20-71	-3.73	5-24-71	-3.10
57	280111N0824535.1	175	76.5	59.27	-	-	4-20-71	-	5-25-71	2.85
58	280104N0824631.1	242	67	33.20	-	-	4-20-71	4.03	5-25-71	4.00
59	280116N0824712.1	250	-	12.86	-	-	4-20-71	1.18	5-25-71	.84
60	280138N0824151.2	120	-	35	-	-	4-20-71	3.30	5-24-71	1.25
61	280158N0824417.1	70	-	50.85	-	-	4-20-71	7.55	5-25-71	8.05
62	280214N0824642.1	-	-	11.30	-	-	4-20-71	5.06	5-25-71	5.28
63	280230N0824550.1	-	-	43.46	-	-	4-20-71	3.37	5-25-71	5.78
64	280254N0824416.2	405	390	65.53	-	-	4-20-71	8.53	5-25-71	8.74
65	280256N0824501.1	64	48	45.58	-	-	4-20-71	7.87	5-25-71	7.84
66	280254N0824635.1	-	-	6.79	-	-	4-20-71	-.61	5-25-71	4.81
				TEST WELLS						
2A	280127N0824232.3	33	-	57.80	-	-	1- 7-71	56.8	-	-
3	280131N0824227.1	80	-	56.95	50	73	1- 7-71	8.0	-	-
4	280135N0824221.2	19	-	57.35	-	-	1- 7-71	54.4	-	-
5	280134N0824232.1	22	-	58.05	-	-	1- 8-71	55.0	-	-
6	280153N0824234.1	19	-	56.51	-	-	1- 8-71	53.5	-	-
7	280153N0824239.1	19	-	57.88	-	-	1- 8-71	54.9	-	-
8	280136N0824247.1	63	-	62.33	-	-	1-11-71	-	-	-
10	280147N0824203.1	40	-	45.31	25	-	-	-	-	-
12	280142N0824203.1	40	-	50.42	15	-	-	-	-	-
14	280200N0824212.1	50	-	45.30	33	48	-	-	-	-
31	280137N0824258.1	80	-	79.68	47	77	-	-	-	-
34	280213N0824237.1	25	-	41.61	20	-	4- 7-71	-	-	-
40	280108N0824338.2	80	-	97.1	-	-	-	-	-	-

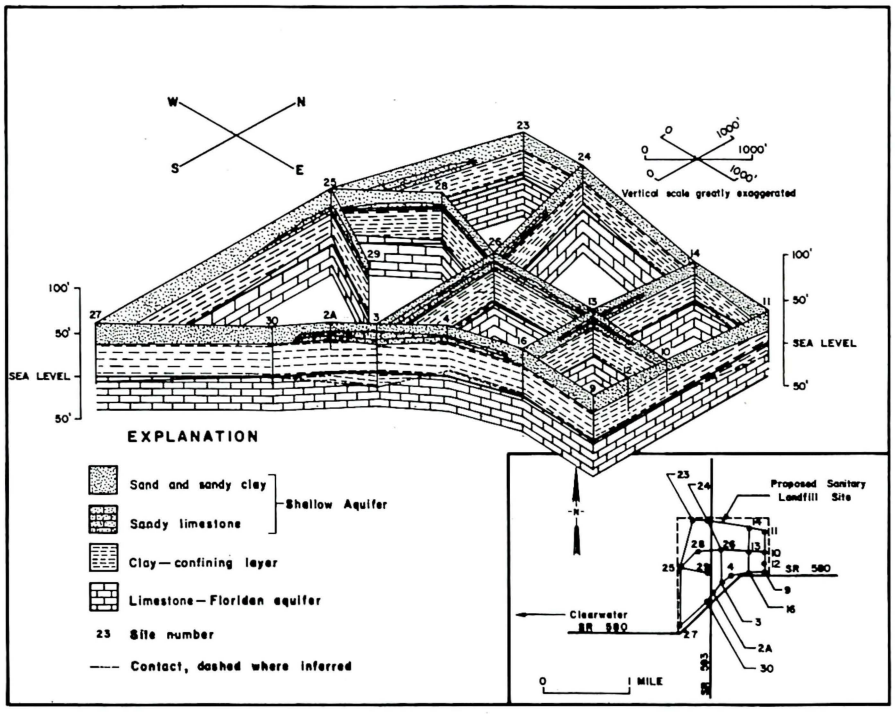


Figure 3. Diagram showing the thickness of shallow aquifer and confining layer overlying the Floridan aquifer in the proposed sanitary landfill site.

aquifer is sandy clay. Within the sand and sandy clay unit is a gray to white, sandy, phosphatic limestone. This sandy limestone underlies the central part of the proposed site (fig. 3). In some places, the sandy limestone forms the base of the shallow aquifer. The sand, sandy clay, and sandy limestone units range in combined thickness from about 10 to 35 feet and average about 15 feet in thickness.

The sand in the upper part of the shallow aquifer ranges in thickness from less than 10 feet near the central part of the site to more than 20 feet along the west boundary of the site. An organically rich, very fine sand occurs along the west boundary. The median particle size of the sand is about 0.15 mm (millimeter) diameter, and the sand is well sorted; 85 percent to 90 percent of the particles range in diameter from 0.10 mm to 0.19 mm. The permeability of the sand, as determined by an aquifer test at a site west of the landfill site, was about 250 gpd per sq ft (gallons per day per square foot). Because the sand is well sorted, the horizontal permeability is probably no more than 10 times the

vertical permeability. Therefore, the vertical permeability probably ranges from 25-100 gpd sq ft.

Figure 4 shows north and east geohydrologic sections through the sanitary landfill site and adjacent area. This figure shows that the water level in the shallow aquifer is near the land surface, the potentiometric surface of the Floridan aquifer is above the top of the Floridan aquifer, and the water level of the shallow aquifer is above the potentiometric surface of the Floridan aquifer.

The shallow aquifer is recharged from local rainfall, and it is not used extensively as a source of water in the landfill area. Locally elsewhere, it is used for irrigating lawns.

Figures 5 and 6 show regional and detailed water-level contours in the shallow aquifer in the general area of the landfill site and infer the direction of water movement in May 1971. The slope of the water surface is controlled by the hydraulic and physical characteristics of water-bearing materials, and local variations in recharge and discharge. Rises in water level are caused by recharge from rainfall. Declines in water level are caused by seepage into streams, lakes, and canals, by evapotranspiration, by pumpage from wells, and by leakage into the underlying Floridan aquifer. Water moves downgradient and normal to the contour lines. The water level in the shallow aquifer is highest, about 90 feet above sea level, a mile west of the proposed landfill site. From this high, which forms a ground-water divide, water moves westward to the Gulf of Mexico or eastward to Old Tampa Bay.

The velocity at which water moves eastward through the shallow aquifer material was calculated using the equation:

$$V = \frac{PI}{7.48S}$$

where:

V = velocity of flow of water through the shallow aquifer, in fpd (feet per day).
P = permeability of the shallow aquifer, in gpd per sq ft.
I = the average hydraulic gradient, in feet per foot.
S = the effective porosity, expressed as a fraction.

Based on a permeability of 250 gpd per sq ft, a hydraulic gradient of 0.02 foot per foot (difference in elevation of 45-foot water-level contour and sea level and the distance from 45-foot water-level contour to Old Tampa Bay (fig. 6) and an effective porosity of 0.25, the velocity would be 2.7 feet per day. At this rate water would take about 2 years to move through the shallow aquifer from the landfill site to the bay.

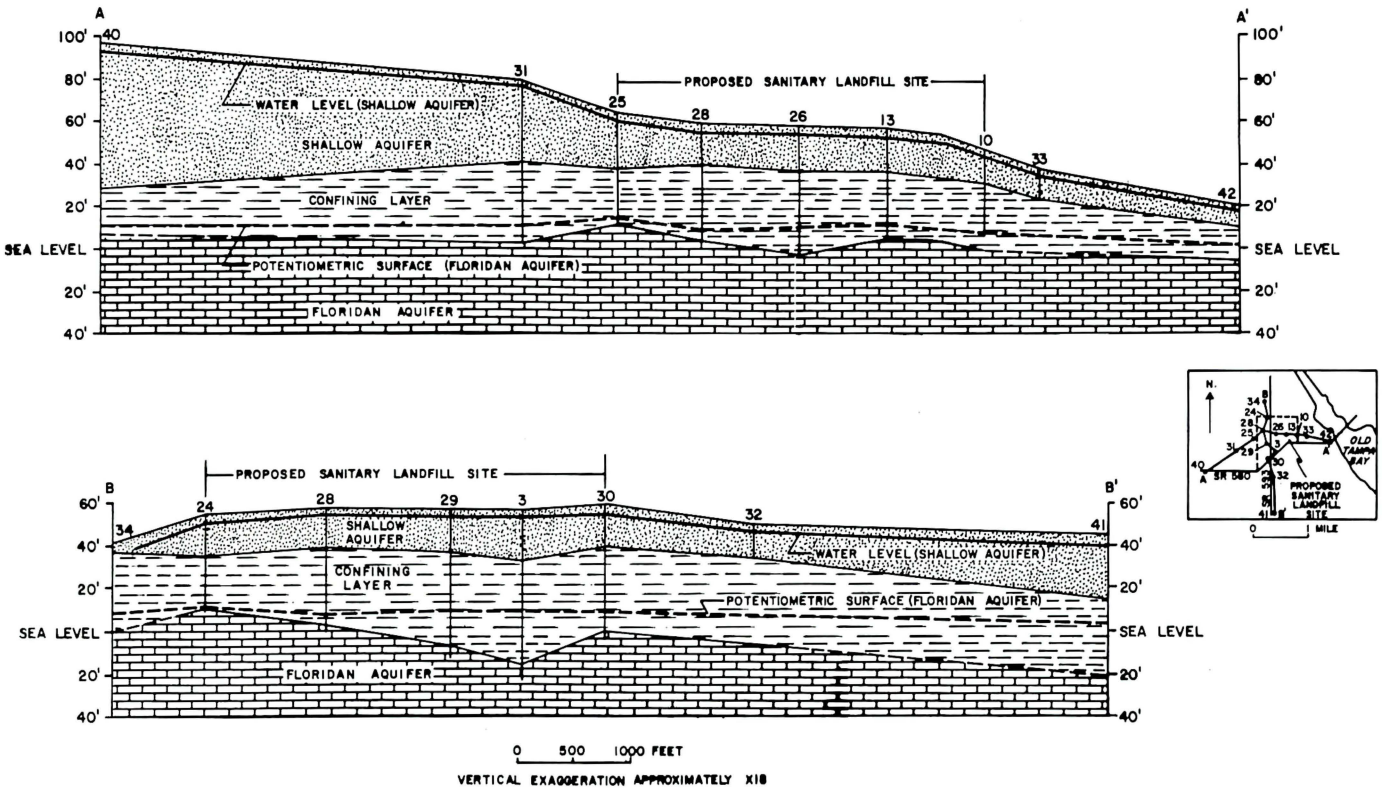


Figure 4. Geohydrologic sections through the proposed sanitary landfill site area.

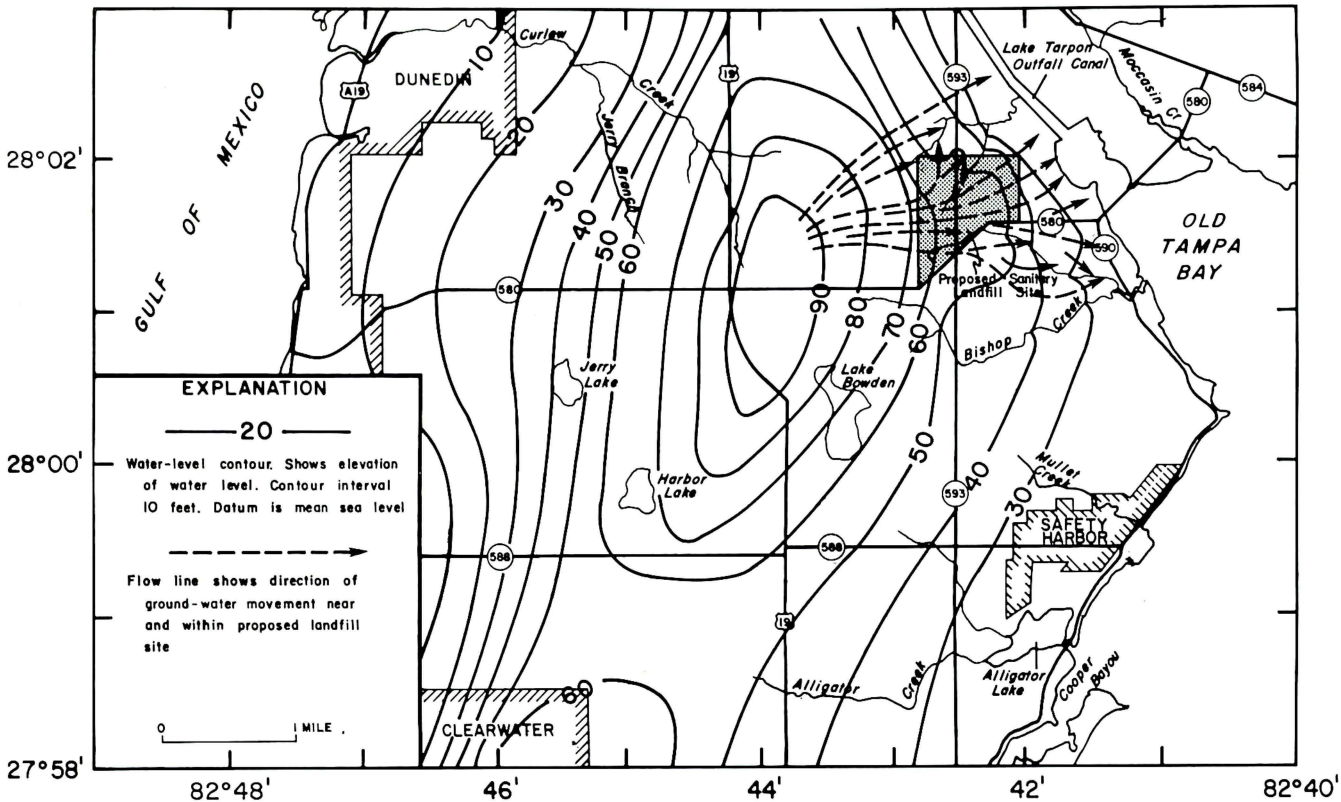


Figure 5. Generalized water-level contours of the shallow aquifer in and near the proposed sanitary landfill site, May 1971.

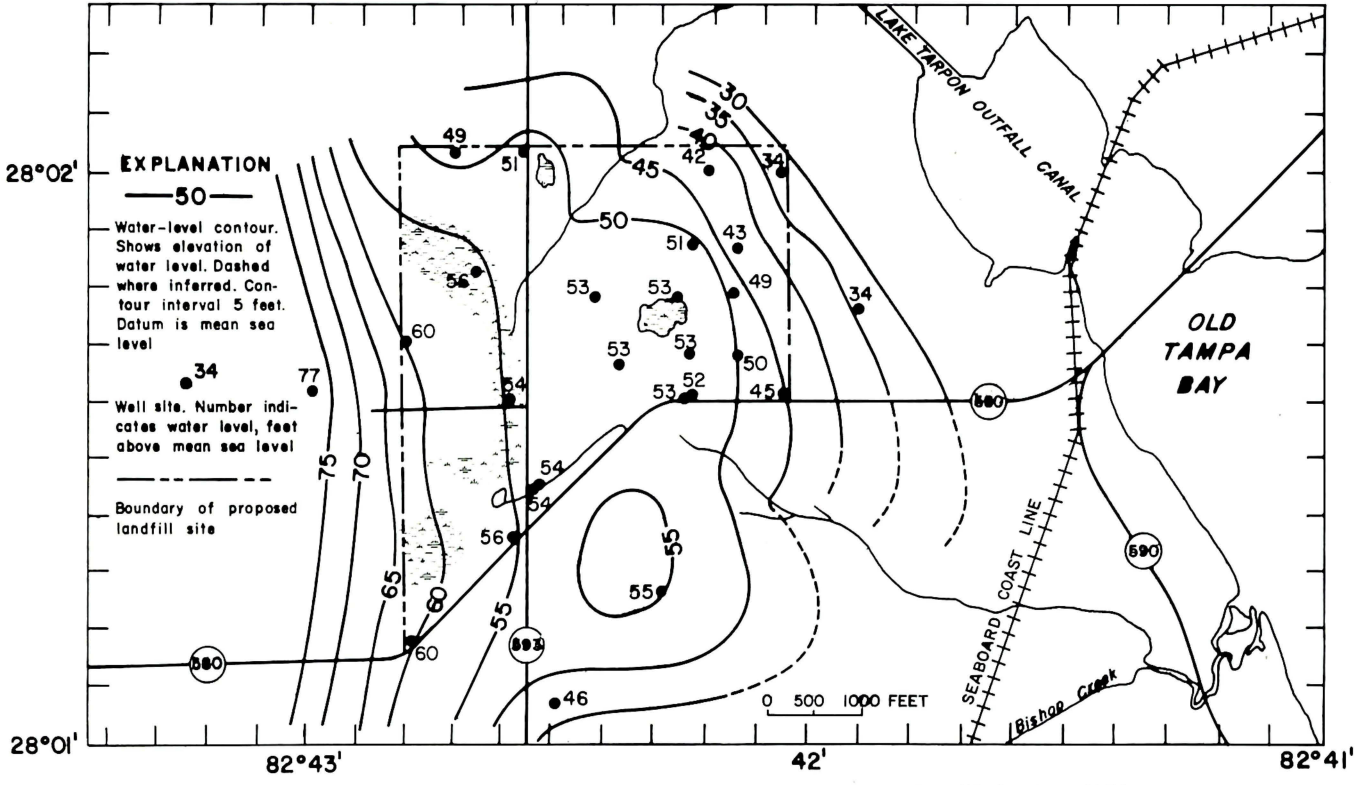


Figure 6. Water-level contours in the shallow aquifer in the proposed landfill site, May 1971.

The quantity of water moving horizontally from the landfill site in the shallow aquifer in a day was calculated using Darcy's law:

$$Q = PIA$$

where:

Q = the quantity of water, in gpd, moving through the shallow aquifer.
P = the permeability of the shallow aquifer, in gpd per sq ft.
I = the hydraulic gradient of the shallow aquifer, in feet per foot.
A = the cross-sectional area of the shallow aquifer at the eastern boundary, in sq ft.

Based on a permeability of 250 gpd per sq ft, a hydraulic gradient of 0.01 foot per foot (gradient across the 45-foot water-level contour, fig. 6), and a cross-sectional area of 49,500 sq ft (determined from the length, 3,300 feet, of the 45-foot water level contour fig. 6), and an average saturated thickness of 15 feet; the water moving horizontally from the sanitary landfill site toward Old Tampa Bay is about 124,000 gpd.

The theoretical velocity and quantity of water moving are based upon the assumption that the water moves at a uniform rate throughout the thickness of the aquifer.

A perimeter ditch could intercept water moving horizontally from the landfill site and reduce ground-water mounding within the site by drainage away from the site. The water could be treated if necessary.

CONFINING LAYER

Underlying the sand and sandy limestone of the shallow aquifer is a layer of pale green, dense, sandy clay of the Hawthorn Formation (?) of middle Miocene Age.

At the landfill site, this clay ranges in thickness from 30 to 50 feet and averages 35 feet thick (fig. 4 and table 2). Tentative identification by X-ray analysis indicates that the clay is a montmorillonite type.

The permeability values shown in table 2 indicate that some water would move vertically through the clay layer. The coefficient of permeability of the clay beneath the proposed site is as low as 4.9×10^{-4} gpd per sq ft. During drilling, some of the clay samples recovered by a split spoon sampler were in part dry indicating that locally the clay has an extremely low vertical permeability.

Table 2. Laboratory analyses and description of materials in the confining layer from test well 3.

Sample No.	Depth (feet)	Coefficient of vertical permeability (gpd per sq ft)	Geohydrologic Unit	Description
3A-3	14.8-15.3	1.59×10^{-2}	Confining layer	Cream-colored, sandy, calcareous clay.
3A-4	21.5-22.0	9.07×10^{-1}	Confining layer	Off white, noncalcareous clay. Sample appears homogeneous.
3A-5	29.0-29.5	3.28×10^{-2}	Confining layer	Off white, noncalcareous. Silty clay; homogeneous. Sample extruded. No stratification noticed.
3A-6	36.0-36.5	4.17×10^{-3}	Confining layer	Light gray, noncalcareous. Light-greenish clay, interbedded with black clay sections. No apparent structure. Some very hard cement sections in core.
3A-7	41.0-41.5	3.19×10^{-3}	Confining layer	Gray noncalcareous clay. Greenish-blue clay with brown streaks. No structure noticed.
3A-8	51.0-51.5	1.64×10^{-3}	Confining layer	Greenish-gray clay; homogeneous. No visible structure.
3A-9	60.5-61.0	4.90×10^{-4}	Confining layer	Dark and light-gray clay. Small part of sample showed carbonate.
3A-10	71.0-71.5	5.39×10^{-3}	Confining layer	Mixture of white and dark gray sandy clay.

The quantity of water moving from the shallow aquifer vertically through the clay layer to the Floridan aquifer was determined using the following form of Darcy's law:

$$Q = (P'/m')\,\triangle hA$$

where:

- Q = leakage through confining bed, in gpd
- P' = coefficient of vertical permeability of confining bed, in gpd per sq ft.
- m'= average thickness of confining bed through which leakage occurs, in feet.
- A = area of confining bed through which leakage occurs, in sq ft.
- H = average difference between the potentiometric surface in the Floridan aquifer and water level in the shallow aquifer in feet.

On the basis of an average coefficient of permeability of 0.002 gpd per sq ft, a clay thickness of 35 feet, and area of 320 acres (about 13,940,000 sq ft) and a 40-foot difference in head between the shallow aquifer and the Floridan aquifer, the amount of water moving vertically through the clay layer in the proposed landfill site is about 32,000 gpd or about one fourth the amount moving through the shallow aquifer to the bay.

Another important property of clay minerals other than the low permeability is their ability to sorb certain ions and retain them in an exchangeable state. Montmorillonite clays, in general, have a high ion-exchange capacity which ranges from about 80 to 150 milliequivalents per 100 grams. Many factors influence the cation exchange capacity, and this accounts for a wide range in exchange capacity values (Grim, 1968).

FLORIDAN AQUIFER

The highly productive Floridan aquifer underlies the Middle Gulf area (Cherry, Stewart, and Mann, 1971). This aquifer supplies virtually all ground-water withdrawals and feeds some of the largest fresh-water springs in the world. Regionally, the aquifer is composed of numerous thick and highly permeable zones of limestone and dolomite. Zones of lesser productivity occur within the aquifer. Some zones yield large volumes of water whereas others yield little water.

The elevation of the top of the Floridan aquifer differs throughout the proposed landfill area. The top of the aquifer is highest, about 10 feet above sea level, just west of the proposed site and is lowest, about 30 feet below sea level, in the east part near the coast (fig. 7).

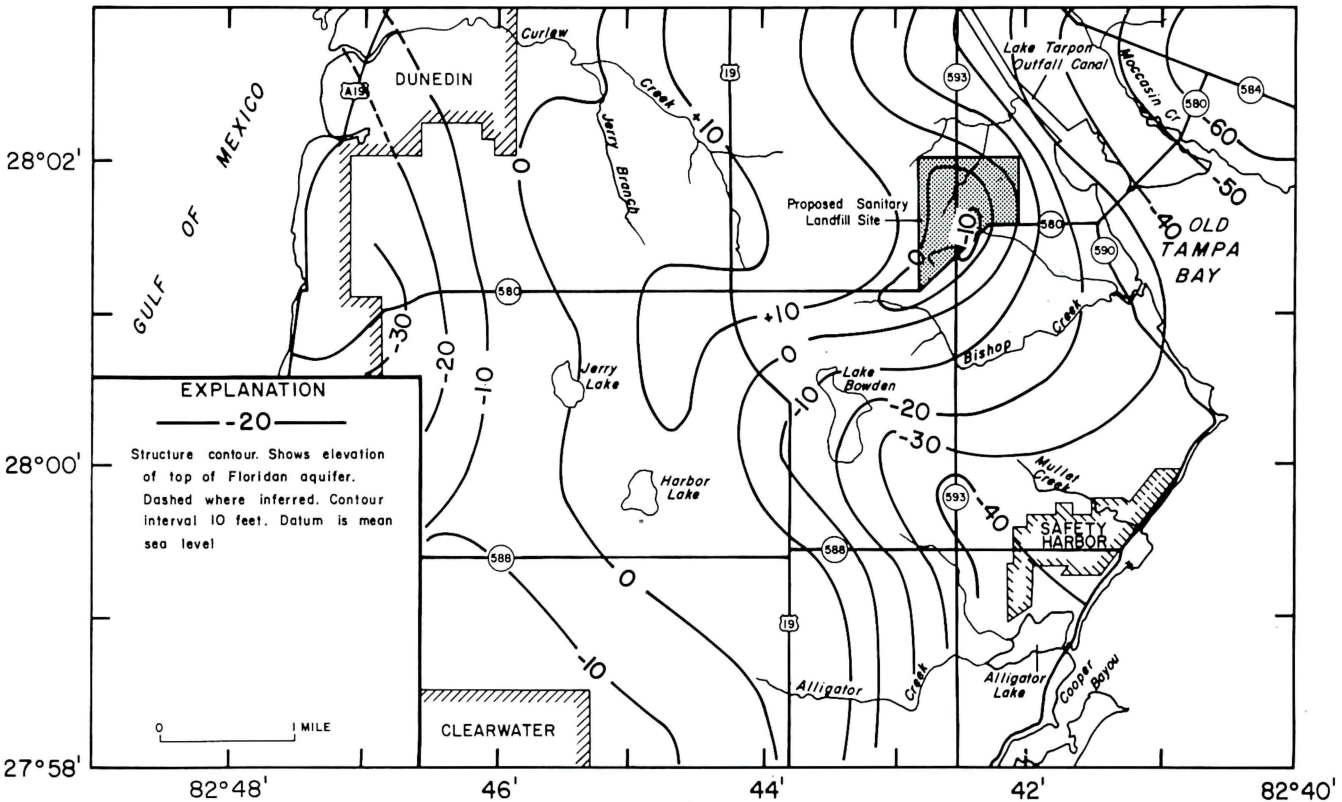


Figure 7. Structure contours on top of Florida aquifer in and near the proposed sanitary landfill site.

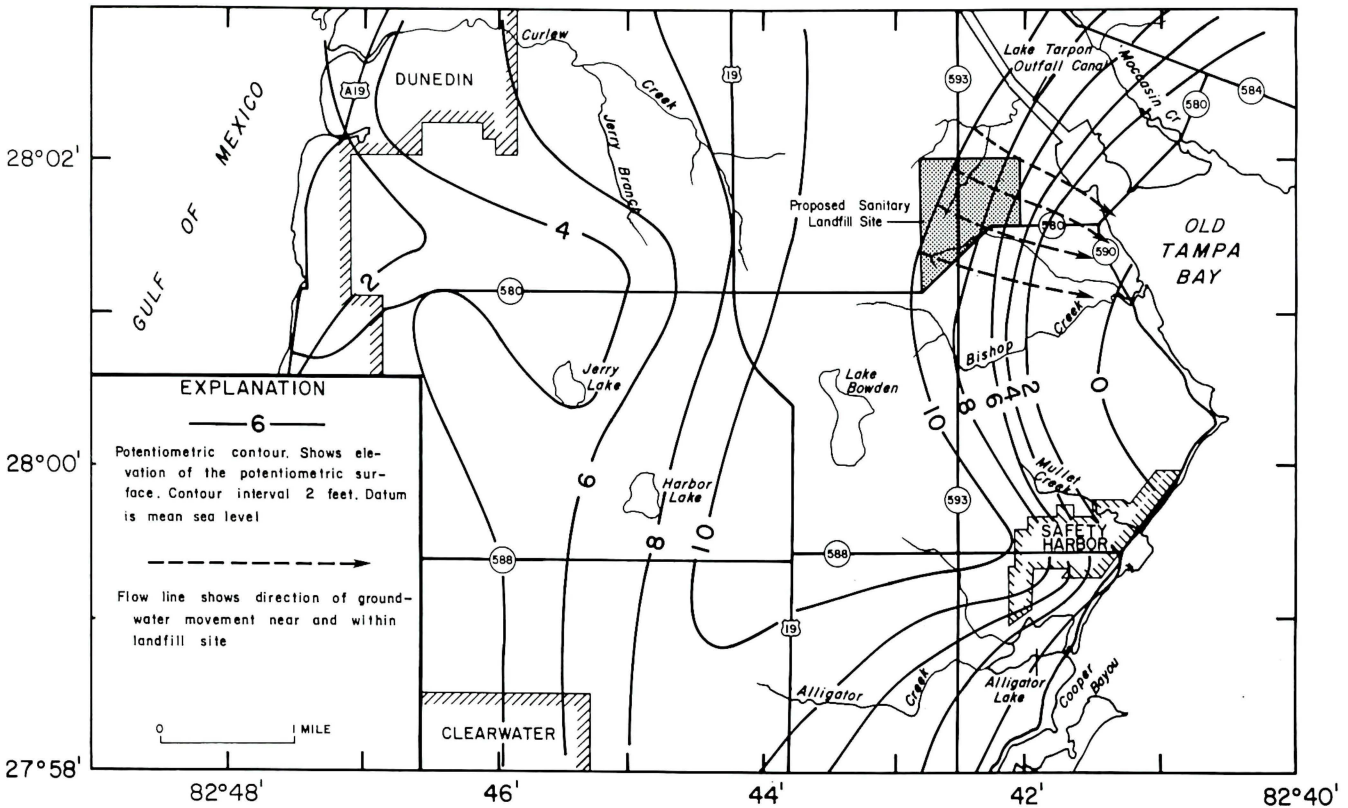


Figure 8. Potentiometric surface of the Florida aquifer in and near the proposed sanitary landfill site, May 1971.

Figure 8 shows that the potentiometric surface of the Floridan aquifer in the area of the landfill site is 6 to 10 feet above msl. Water movement in the Floridan aquifer in the area of the proposed site is generally eastward, toward Old Tampa Bay. The potentiometric surface is highest in the same general area as the highest land elevation and the highest water level in the shallow aquifer. (compare figs. 2 and 7). This potentiometric high forms a ground-water divide.

Water in the upper part of the Floridan aquifer generally contains less than 250 mg/l (milligrams per liter) of chloride. Salt water occurs in the lower part of the Floridan aquifer.

The city of Dunedin, about 4 miles west of the proposed sanitary landfill site, receives all of its water, and Clearwater, about 7 miles southwest, receives part of its water from the Floridan aquifer. A natural ground-water divide in the potentiometric surface of the Floridan aquifer occurs between the well fields of both cities and the proposed sanitary landfill site (fig. 8).

STREAMS

The unnamed tributary to the Lake Tarpon outfall canal is the principal stream draining the area of the proposed landfill site. The headwaters for this stream is a marsh near the center of the landfill site. The marsh is drained by a canal that connects with the tributary. Near the north boundary of the site, the stream has cut through the shallow sand and sandy limestone of the shallow aquifer to the clay of the confining layer. Flow was observed, although not measured, during the 1971 dry season.

The discharge from the shallow aquifer to the stream was calculated using the equation:

$$Q = PIA$$

where:

- Q = the quantity of water in gpd moving through the shallow aquifer to the stream.
- P = the permeability of the shallow aquifer, in gpd per sq ft.
- I = the hydraulic gradient in the shallow aquifer, feet per foot.
- A = the cross sectional area, in sq ft of the aquifer contributing water to the stream.

Assuming the stream fully penetrates the shallow aquifer and has a depth of 15 feet, a length of 2,500 feet that contributes water to the stream (a cross sectional area of 37,500 sq ft), and the shallow aquifer has a hydraulic gradient of 0.01 foot per foot and a permeability of 250 gpd per sq ft, the discharge from the shallow aquifer to the stream is 190,000 gpd.

EVALUATION OF THE PROPOSED LANDFILL SITE

According to Stewart and Hanan (1970), a sanitary landfill should be in an area where the underlying deposits are relatively impermeable and where the leachate from the refuse is contained or its movement from the site is retarded. Sites underlain by highly permeable sand are generally unfavorable. Sites directly underlain by fractured and cavernous limestone should be avoided because of the unpredictability of the direction and rate of ground-water movement in such materials. Other areas that should be avoided are swamps and marshes tributary to streams and those that contain sinkholes.

On the basis of criteria by Stewart and Hanan (table 3) and other hydrologic considerations, the proposed sanitary landfill site has both favorable features and unfavorable features. The favorable features include:

1. The combined thickness of the sand, sandy limestone and clay units which overlie the Floridan aquifer is about 50 feet.
2. The land surface ranges in elevation from 40 to 65 feet;parts of the site can be drained.
3. The site is in an area of minimal urban development.
4. A clay layer separates the shallow aquifer from the Floridan aquifer. The clay is a montmorillonite type which generally has a high ion-exchange capacity, a selective (sorbing) capacity for organic compounds and will tend to sorb materials from water passing through it.
5. The clay layer will retard vertical flow from the shallow aquifer to the Floridan aquifer. The amount of water moving through the clayey material is probably less than 32,000 gpd.
6. The Floridan which is the principal aquifer, shows some evidence of salt-water encroachment in the general area of the landfill site, and thus is unlikely to be extensively developed in this area as a municipal water supply.
7. The proposed sanitary landfill site is on the east slope of a surface- and ground-water divide. All the municipal water-supply wells for Clearwater and Dunedin are on the west slope of the divide.

The unfavorable hydrologic features are:

1. The uppermost part of the deposits that underlie the site forms a shallow aquifer.
2. Although the site is more than 40 feet above msl, part of the site is not well drained.

Table 3. Evaluation of the proposed site according to Stewart and Hanan's criteria

	Stewart and Hanan's Criteria	Proposed Site	Remarks
1.	Type of unconsolidated material. Favorable: clay, silty clay, clayey silt, silt. Unfavorable: sand.	Favorable	Upper material (shallow aquifer) is sandy and grades to a clay with depth. The permeability of sand is low. The lower unconsolidated material is clay and nearly impermeable.
2.	Thickness of unconsolidated materials. Favorable: at least 25 feet. Unfavorable: less than 15 feet.	Favorable	Unconsolidated material is greater than 50 feet thick.
3.	Site topography. Favorable: adequate drainage not subject to flooding. Unfavorable: low swampy areas; areas subject to flooding; sinkholes and areas near sinkholes; along stream channel hydraulically connected with Floridan aquifer.	Favorable	Land surface elevation is greater than 40 feet above msl. Although parts of the site are marshy, it could be drained.
4.	Ground-water levels. Nonartesian aquifer. Favorable: greater than 15 feet below land surface. Unfavorable: less than 5 feet below land surface.	Unfavorable	The water level of the shallow aquifer is about 3 to 4 feet below the land surface. Therefore, a perimeter canal around all parts of the landfill would be needed to lower the water table in the working area and to intercept water leaving the site.
	Artesian aquifer. Favorable: Potentiometric surface at least 5 feet above water table. Unfavorable: Potentiometric surface near or below the water table.	Unfavorable	The potentiometric surface is about 40 feet below the water level of the shallow aquifer. However, a massive clay layer of low permeability retards flow from the shallow aquifer to the Floridan aquifer.
5.	Character of limestone aquifer. Favorable: dense, unfractured. Unfavorable: fractured and cavernous.	Unfavorable	Floridan aquifer is probably fractured and cavernous.
6.	Relation to public water supply wells. Favorable: at least several miles down-gradient from large pumping withdrawals. Unfavorable: Adjacent to or within the immediate cone of influence of large-scale pumping.	Favorable	Nearest public-supply wells are beyond the ground water divide and at least 3 miles away.

3. The water level of the shallow aquifer is above the potentiometric surface of the Floridan aquifer. Therefore, water will move from the shallow aquifer to the Floridan aquifer.
4. The Floridan aquifer underlying the area is probably fractured and cavernous.
5. The proposed site is in an area where the water table is generally less than 5 feet below land surface.
6. The leachate from the refuse will contaminate the shallow aquifer within and downgradient from the landfill site.
7. This contamination will move by stream (190,000 gpd) and through the shallow aquifer (124,000 gpd) toward Old Tampa Bay.

The foregoing unfavorable features indicate that at least the following precautions are desirable before use of the site:

1. Installing a canal or ditch or series of shallow wells around the site to intercept water leaving the site and lower the water level in the working area. If necessary the water could be treated. This will minimize or prevent contamination downgradient from the landfill site.
2. Maintaining a monitoring system of wells at least in a downgradient direction to determine the nature and extent of movement of contaminants.
3. Checking the private water supplies in the general area of the proposed site periodically to provide warning of incipient contamination.
4. Providing an alternative source of water for domestic use in the general area of the proposed landfill site in the event contamination should occur.

SUMMARY

The proposed landfill site is on the east flank of a topographic ridge at an elevation of 40-65 feet above sea level. The upper 15 feet of material at the landfill site is chiefly sand. The material becomes more clayey with depth and becomes a clay at about 20 feet. The sand of the shallow aquifer has an estimated permeability of about 250 gpd per sq ft. About 124,000 gpd of water moves laterally from the sanitary landfill site through shallow aquifer materials toward Old Tampa Bay at a rate of about 2.7 feet per day.

The top of the clay layer underlying the shallow aquifer occurs at an elevation of about 40 feet above sea level. This clay layer is about 35 feet thick. The clay is of a montmorillonite type and has an estimated average permeability

of 0.002 gpd per sq ft. Water moves vertically from the shallow aquifer on the 320-acre site through the thick clay layer at a rate of about 32,000 gpd.

Most of the water for domestic and municipal uses in this area and on the peninsula is obtained from the Floridan aquifer. Water from deep high-production wells generally contains some salt. Water from relatively shallow domestic wells contains little salt.

Geohydrologic features of the site are both favorable and unfavorable with respect to its use as a sanitary landfill. With proper precautions the unfavorable features could be modified or partly controlled and the site made hydrologically suitable.

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